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MEMORANDUM

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for the

U. S. Air Force

SERVICE REPORT

FREE-SPINNING-TUNNEL INVESTIGATION OF A 1/40-SCALE MODEL
OF THE MCDONNELL F-101A AIRPLANE

COORD. NO. AF-AM-87

By James S. Bowman, Jr., and Frederick M. Healy

Langley Research Center
Langley Field, Va.

[redacted]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

An investigation has been made in the Langley 20-foot free-spinning tunnel of a 1/40-scale model of the McDonnell F-101A airplane to alleviate the unfavorable spinning characteristics encountered with the airplane.

The model results indicate that a suitable strake extended on the inboard side of the nose of the airplane (right side in a right spin) in conjunction with the use of optimum control recovery technique will terminate spin rotation of the airplane. It may be difficult to recover from subsequent high angle-of-attack trimmed flight attitudes even by forward stick movement. The optimum spin-recovery control technique for the McDonnell F-101A is simultaneous full rudder reversal to against the spin and aileron movement to full with the spin (stick full right in a right erect spin) and forward movement of the stick immediately after rotation stops.

INTRODUCTION

At the request of the U. S. Air Force, a brief investigation has been made of a 1/40-scale model of the McDonnell F-101A airplane in the Langley 20-foot free-spinning tunnel. The F-101A is a low swept-wing, twin jet engine, fighter airplane. The purpose of the investigation was to determine the size of antispin strake required to obtain satisfactory spin-recovery characteristics.

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*Title, Unclassified.

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SYMBOLS

b	wing span, ft
S	wing area, sq ft
$\bar{c}$	mean aerodynamic chord, ft
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-ft^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slug/cu ft
μ	relative density of airplane, $\frac{m}{\rho Sb}$
α	angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg
ϕ	angle between span axis and horizontal, deg
V	full-scale true rate of descent, ft/sec
Ω	full-scale angular velocity about spin axis, rps

MODEL AND TESTING TECHNIQUES

The 1/40-scale model of the McDonnell F-101A airplane was furnished by the U. S. Air Force and was prepared for testing by the Langley Research Center of the National Aeronautics and Space Administration. A three-view drawing of the model as tested is shown in figure 1. The dimensional characteristics of the airplane are presented in table I.

The mass characteristics for the loading of the airplane and for the loading tested on the model are presented in table II. The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 30,000 feet (ρ = 0.000889 slug/cu ft).

A remote-control mechanism was installed in the model to actuate the controls for the recovery attempts. Sufficient torque was exerted on the controls for the recovery attempts to reverse them fully and rapidly.

The following normal maximum control deflections (measured perpendicular to the hinge lines) were used during the test program:

Rudder, deg	25 right, 25 left
Horizontal tail, deg	20 trailing edge up, 10 trailing edge down
Ailerons, deg	25 up, 25 down

General descriptions of model testing techniques, methods of interpreting test results, and correlation between model and airplane results are presented in reference 1.

RESULTS AND DISCUSSION

The results of the model tests are presented in chart 1. Spins to the pilot's right and left were similar, and the data are arbitrarily presented in terms of right spins. The notation "no spin" on the chart indicates that the model recovered from the spin rotation imparted to it on launching into the tunnel without control movement.

The investigation was undertaken when spin-recovery problems were encountered during the flight-test program of the airplane. In order to reproduce as closely as possible the spin characteristics of the airplane, a series of exploratory tests (results not presented) were made to determine a modification which would result in a model spin with comparable characteristics to the airplane spin. This condition was obtained with strake A (fig. 2) mounted on the outboard side of the nose (left side in a right spin). With this modification, the spin characteristics of the model closely simulated those observed with the airplane; that is, flat spins with unsatisfactory recovery characteristics were obtained. Reference 1 discusses differences due to scale effects on long noses between model and airplane spins.

The spin and recovery characteristics of the modified model with strake B (fig. 2) mounted on the inboard side of the nose (right side in a right spin) are presented in chart 1. As indicated in the chart, termination of the spin rotation was obtained by proper manipulation of the rudder and aileron controls. However, the model subsequently entered a high angle-of-attack slide (about 55°) for stick back and neutral conditions and, even with the stick forward, the model sometimes entered the flat glide. The inherent longitudinal characteristics of this design lead to high angle-of-attack trim attitudes and even the recommended recovery technique can not assure return to normal flight attitudes. The recommended technique for spin recovery is full rudder reversal to against the spin and simultaneous movement of the ailerons to full with the spin, and forward movement of the stick immediately after the rotation stops. This control technique is recommended for attempting recovery from any erect spins encountered by the airplane.

As previously indicated, strake B was mounted on only one side of the fuselage (right side for right spin) and strake A was mounted on the opposite side in order to simulate the airplane spinning characteristics. It is recommended, however, that strake B be mounted on both sides of the fuselage of the airplane so that the desired spin-recovery characteristics can be obtained for both right and left spins.

SUMMARY OF RESULTS

From a free-spinning-tunnel investigation of a 1/40-scale model of the McDonnell F-101A airplane, the following summary is considered applicable to the spin and recovery characteristics of the airplane at 30,000 feet:

1. Spin-recovery characteristics of the basic airplane will be unsatisfactory. A suitable strake fixed on both sides of the nose of the airplane will provide termination of the spin rotation by use of the optimum control technique. The subsequent flight path may result in a high angle-of-attack glide from which it may be difficult to obtain normal flight attitudes even by forward movement of the atick.

2. The optimum control technique for recoveries from erect spins of the airplane with an antispin strake installed on both sides of the fuselage nose is simultaneous full rudder reversal to against the spin and aileron movement to full with the spin (stick full right in a right erect spin), and forward movement of the stick immediately after the rotation stops.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., January 15, 1959.

REFERENCE

1. Neihouse, Anshal I., Klinar, Walter J., and Scher, Stanley H.: Status of Spin Research for Recent Airplane Designs. NACA RM L57F12, 1957.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE MCDONNELL F-101A AIRPLANE

Overall length, ft	67.45
Wing:	
Span, ft	39.69
Area, sq ft	419.19
Aspect ratio	3.76
Incidence, deg	1
Dihedral, deg	0
Sweepback (33.218 percent chord), deg	35
Airfoil section:	
Root	NACA 65A007 modified
Tip	NACA 65A006 modified
Aileron:	
Span, each, ft	7.48
Root chord, in.	30.00
Tip chord, in.	17.32
Horizontal tail:	
Total area, sq ft	74.47
Span, ft	15.75
Aspect ratio	3.33
Dihedral, deg	10
Sweepback (29.34 percent chord), deg	35
Airfoil section:	
Root	NACA 65A007 modified
Tip	NACA 65A006 modified
Vertical tail:	
Area, above fuselage (excluding dorsal), sq ft	75.29
Area of dorsal, sq ft	1.27
Span, ft	7.5
Aspect ratio	0.75
Sweepback (59.055 percent chord), deg	35
Airfoil section:	
Root	NACA 65A007
Tip	NACA 65A007
Rudder:	
Area, back of hinge line, sq ft	12.20
Span, ft	5.95
Root chord, in.	30.93
Tip chord, in.	18.32
Hinge-line location, percent chord	82.00
Sweepback of hinge line, deg	25.40

[redacted]

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADING OF THE MCDONNELL F-101A AND FOR LOADING TESTED ON THE 1/40-SCALE MODEL

[Values given are full scale, and moments of inertia are given about the center of gravity]

Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-feet^2			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	30,000 feet	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane											
Combat gross weight	36,950	0.319	------	33.05	88.44	18,650	167,500	177,000	-822×10^{-4}	-52×10^{-4}	874×10^{-4}
Model											
Combat gross weight	37,211	0.315	0.0815	33.28	89.06	22,432	167,677	174,283	-797×10^{-4}	-36×10^{-4}	833×10^{-4}

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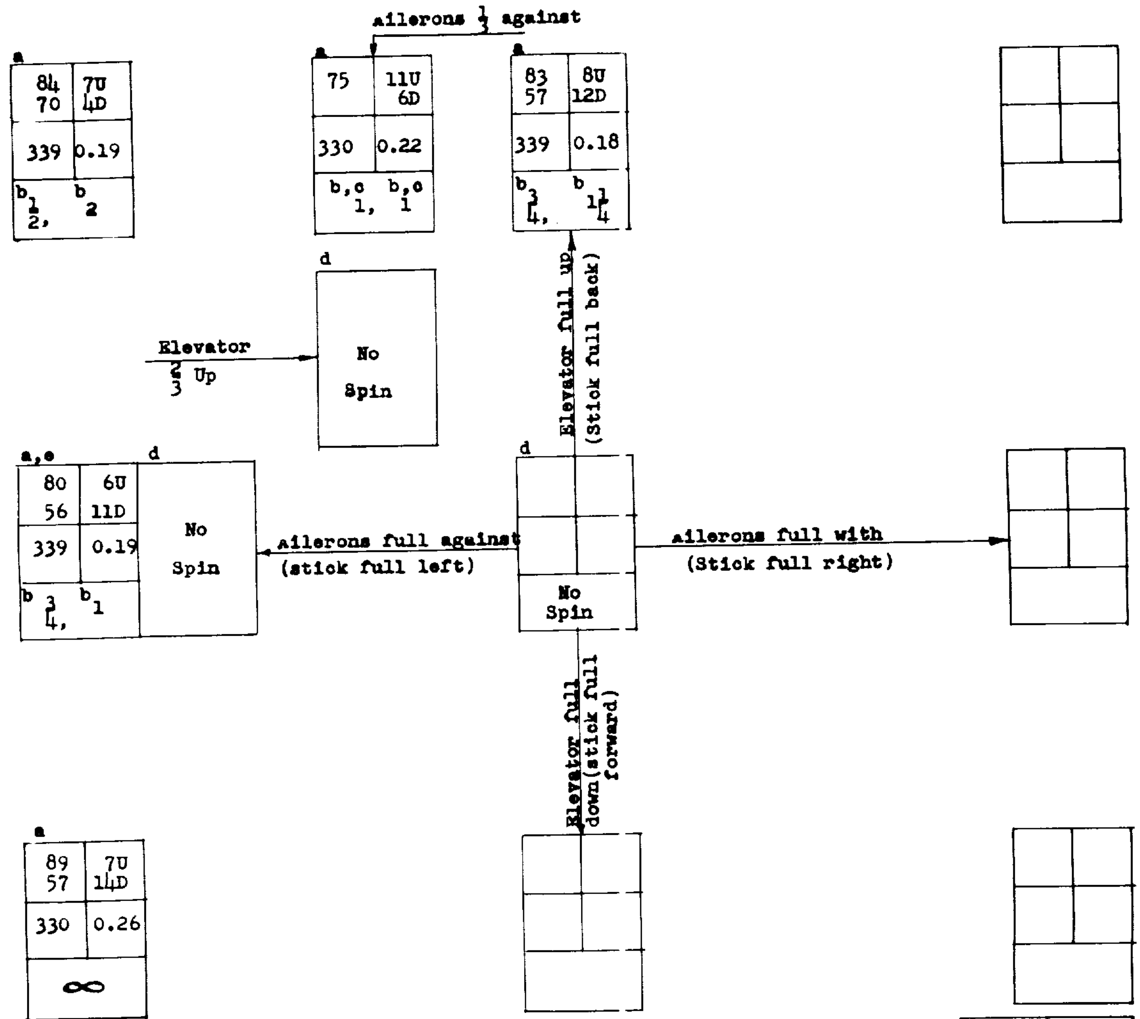
CHART 1.-SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal and simultaneous movement of the ailerons to full with the spin unless otherwise indicated (recovery attempted from, and developed-spin data presented for, rudder-full with spins)]

Airplane Modified F-101A	Attitude Erect	Spin direction simulated Right	Loading (see table II) Combat Gross Weight	Engine rotation not simulated
STRAKE On Model B	Altitude 30,000 ft		Desired center-of-gravity position 31.9 percent $\bar{c}$	

Model values converted to full scale   U-inner wing up   D-inner wing down



- a Oscillatory spin, range or average values given.
- b Recovered in a flat glide.
- c Recovery attempted by reversing the rudder to 2/3 against the spin and simultaneously moving the ailerons to 2/3 with the spin.
- d Entered a flat glide.
- e Two conditions possible.

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

[redacted]

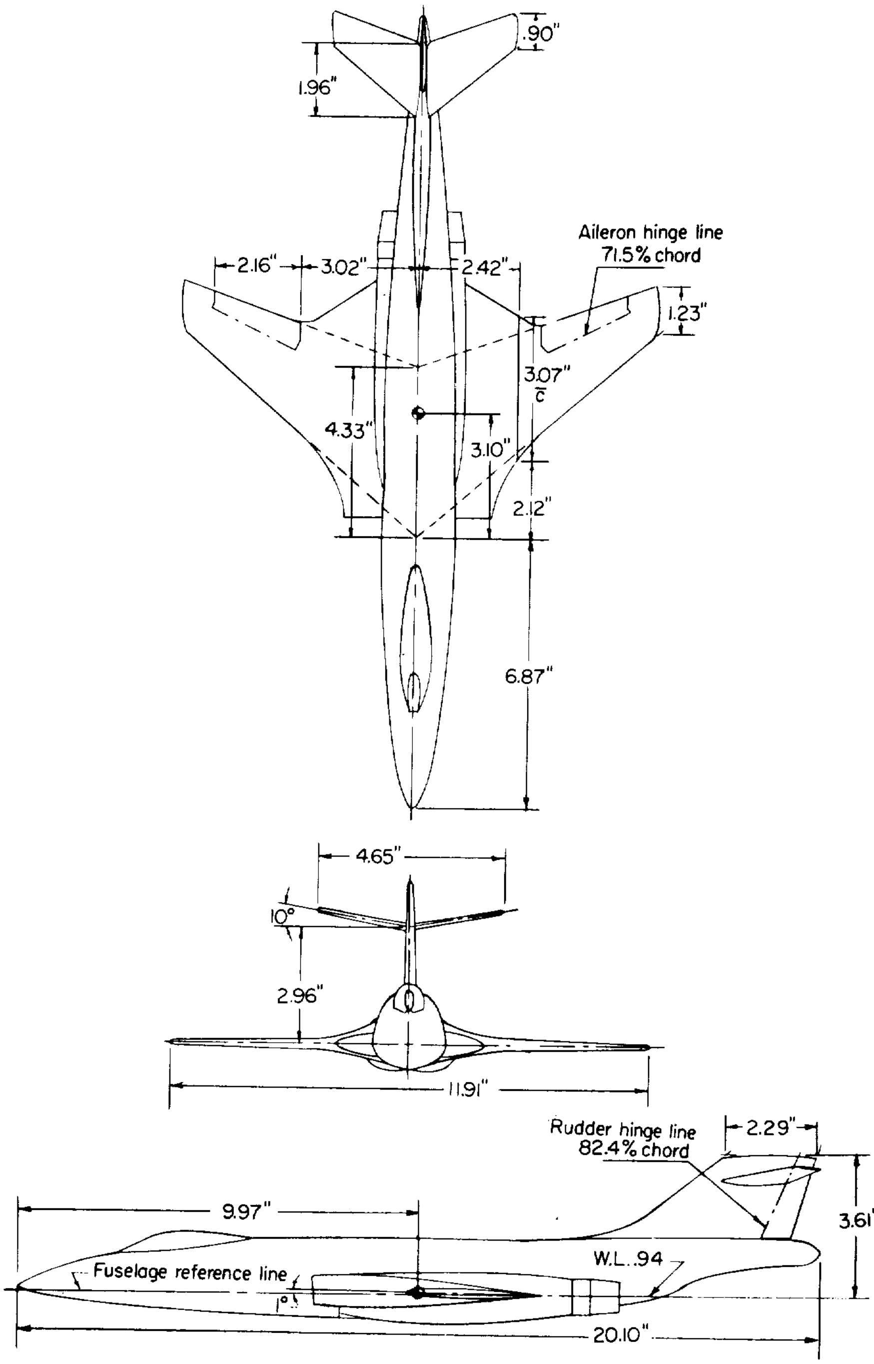


Figure 1.- Three-view drawing of the 1/40-scale model of the McDonnell F-101A airplane. Center-of-gravity position indicated is for the combat gross weight loading.

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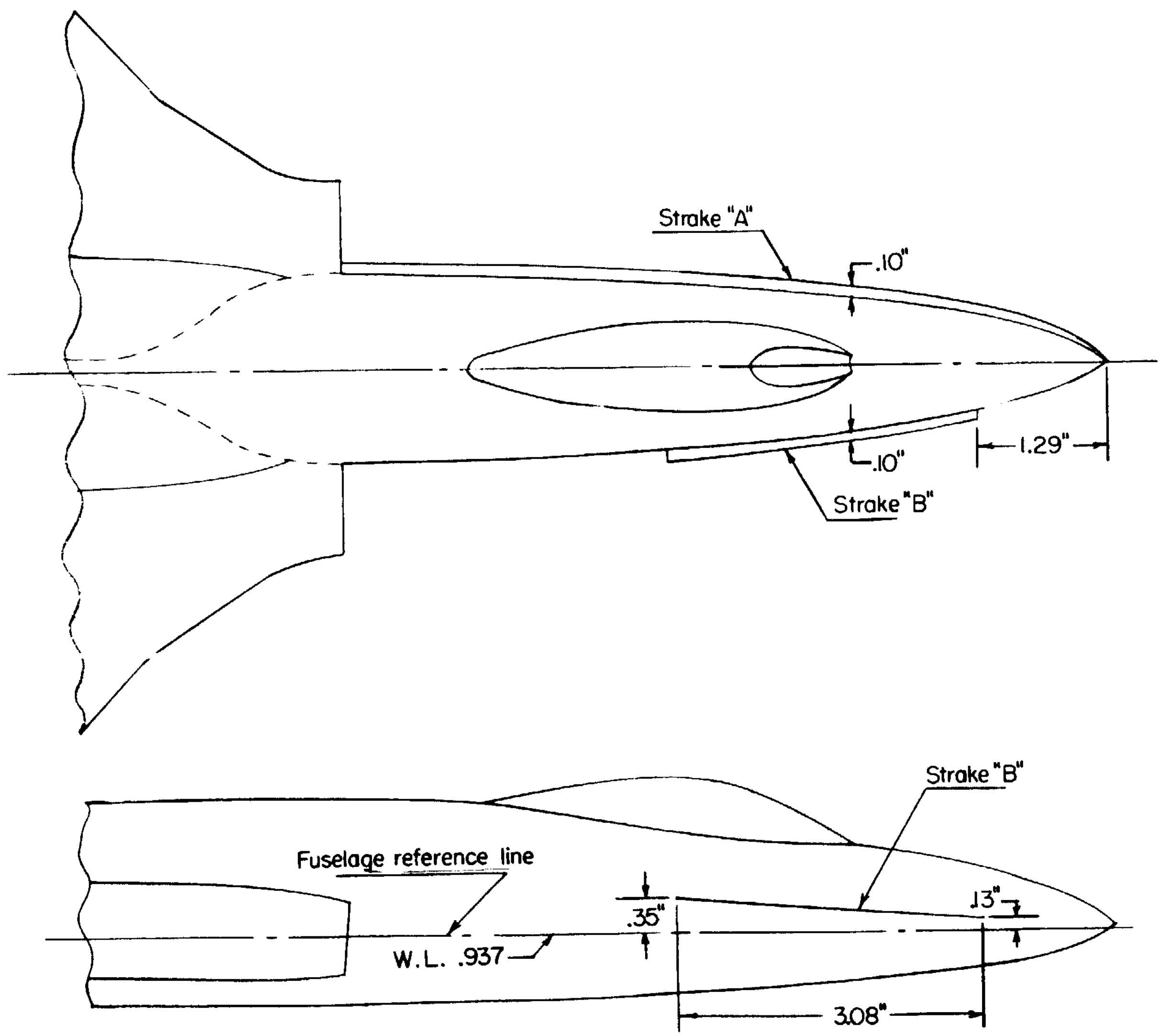

Figure 2.- Strakes investigated on the model. Vertical location of strake A is on the fuselage reference line. Dimensions are model scale.

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ABSTRACT

A modification was determined to alleviate unsatisfactory spin-recovery characteristics of the basic airplane and the optimum spin-recovery control technique was evaluated.

INDEX HEADINGS

Airplanes - Specific Types	1.7.1.2
Spinning	1.8.3
Mass and Gyroscopic Problems	1.8.6
Piloting Techniques	7.7

*Title, Unclassified.

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